SECTION 5
Summary of Tissue Data

This section summarizes bivalve (butter clam) data collected in 2005, 2006, and 2007 for the ambient and outfall monitoring programs and macroalgae (sea lettuce) data collected in 2005.

5.1 Shellfish Tissue

Shellfish tissue samples, composed entirely of butter clams (*Saxidomus giganteus*), were collected each year and all data are presented in Appendix C. Station locator maps are provided in Section 2, along with specific station information such as matrix, parameters, and frequency measured.

In 2005, samples were collected in August from four outfall stations; KSHZ03 (Carkeek Park), KSSN05 (West Point), LSKS01 (Alki), MSJL01 (Vashon Island), and three ambient stations; JSVW04 (Point Wells), KSLU03 (Golden Gardens), MTLD03 (Normandy Park). In 2006, the shellfish monitoring program was expanded to twice-yearly sampling, with samples collected in both March and August. One ambient shellfish sampling station was added at Edwards Point (ITEDWARDSPT), near the King-Snohomish County line, and the Alki station was moved to a new location (LSKS04). Twice-yearly sampling continued in 2007 and one outfall shellfish station was added at West Point (KSSN04).

Samples were composited from the tissues of multiple clams, generally between 5 and 10, to provide sufficient sample matrix. Lipid and metal analyses were performed on all samples collected in 2005, 2006, and 2007. Organic analyses, including semivolatile organic compounds, chlorinated pesticides, and polychlorinated biphenyls (PCBs), were only performed on samples collected during the August 2005 sampling event.

5.1.1 Lipids

Shellfish tissue samples were analyzed for lipid content since the concentration of lipids in the organism's tissue can affect the accumulation of certain compounds. Lipid concentrations can also be an indicator of the overall health and reproductive state of the organism. Lipid concentrations in the shellfish tissue samples collected in 2005, 2006, and 2007 are shown in Table 5-1.

Figure 5-1 summarizes lipid concentrations in shellfish tissue samples collected from 1998 through 2007 at the seven most-frequently sampled stations. Note that not every station was collected during each monitoring year. The figure shows that, in spite of some temporal variation at each station, the mean lipid concentration is similar across all seven stations, ranging from 0.52 to 0.64 percent.

Table 5-1. 2005 to 2007 Shellfish Tissue Percent Lipid Concentrations

Sampling Event	Minimum	Maximum	Mean
August 2005	0.34	0.60	0.46
March 2006	0.24	0.44	0.37
August 2006	0.14	0.38	0.29
March 2007	0.27	0.86	0.61
August 2007	0.59	1.13	0.90

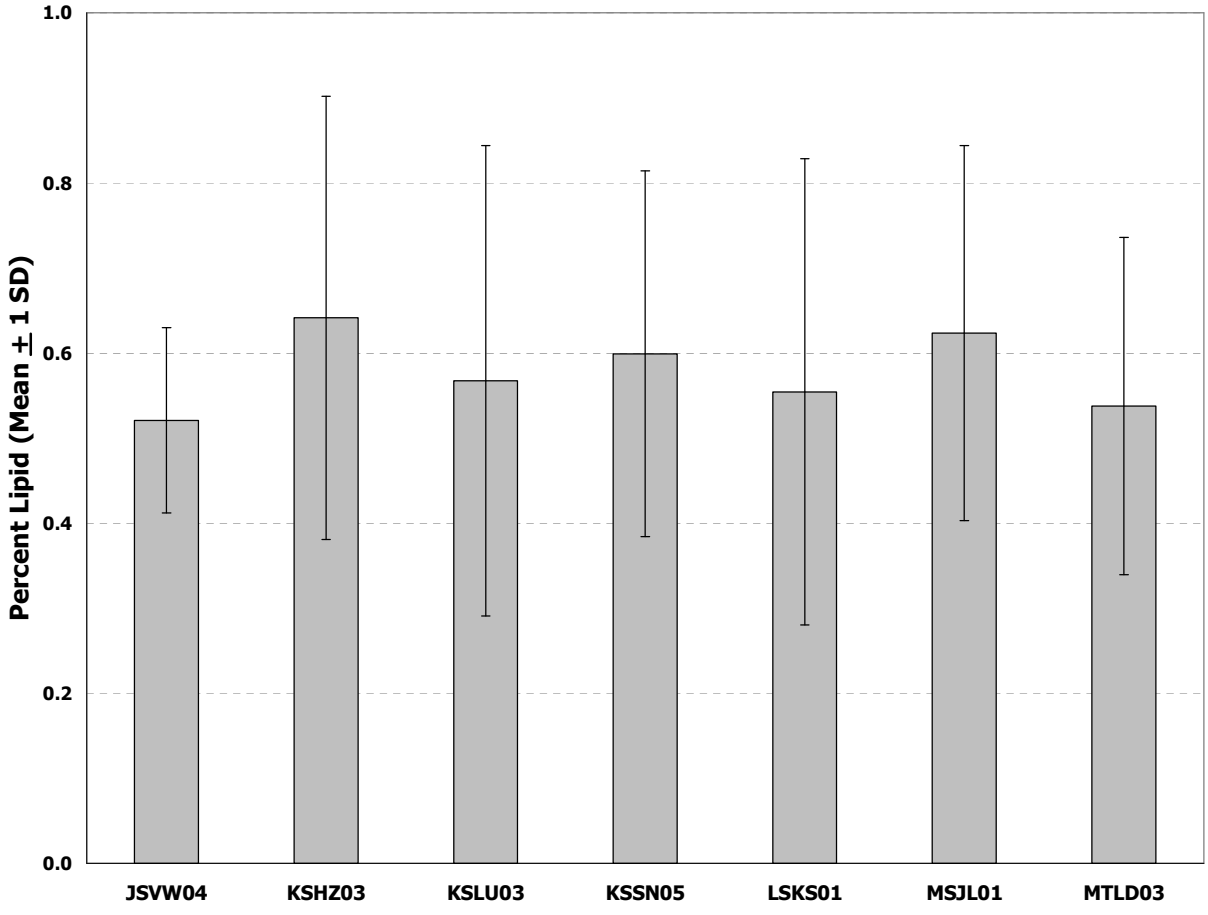

Figure 5-1. Shellfish Tissue Mean Lipid Concentrations (%) by Station – 1998 to 2007

5.1.2 Metals

All shellfish tissue samples were analyzed for 14 metals in 2005, 2006, and 2007; the crustal metals aluminum, iron, and manganese, and the trace metals arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. Beryllium was not detected in any of the samples. The other 13 metals were detected in all samples.

Washington State has not promulgated criteria or guidance for acceptable levels of metals in shellfish tissue. The United States Food and Drug Administration (FDA) has, however, established guidance values termed Levels of Concern for arsenic, cadmium, chromium, lead, and nickel in bivalves (clams, mussels, oysters). The FDA has also established an Action Level of 1.0 mg/Kg for mercury in fish and shellfish tissues. Food products exceeding the Action Level cannot be commercially traded, an important distinction from the Levels of Concern. Table 5-2 summarizes the ranges of shellfish tissue concentrations detected in 2005, 2006, and 2007 for arsenic, cadmium, chromium, lead, mercury, and nickel and compares them to FDA guidance for metals in shellfish. All of the detected concentrations are well below the FDA Levels of Concern for arsenic, cadmium, chromium, lead, and nickel (FDA, 1993a, b, c, d, e) and the Action Level for mercury (FDA, 1995).

Table 5-2. 2005 to 2007 Shellfish Tissue Metals Concentrations Compared to FDA Criteria

Metal	Minimum	Maximum	Level of Concern	Action Level
Arsenic	1.75	4.72	55	--
Cadmium	0.0410	0.0864	3	--
Chromium	0.160	0.550	11	--
Lead	0.037	0.290	0.8	--
Mercury	0.00323	0.0114	--	1.0
Nickel	0.495	1.18	80	--

Note: All values in mg/Kg on a wet-weight basis.

Metal concentrations in shellfish tissue have shown little variation, either spatially or temporally, over the course of the shellfish monitoring program. Figure 5-2 compares shellfish tissue concentrations of four metals between 1998 and 2007 at the five locations sampled most frequently. The figure shows the mean concentration ($\pm$ 1 standard deviation) of chromium, copper, nickel, and zinc. Note that, for comparative purposes, these metals' data have been normalized to dry weight.

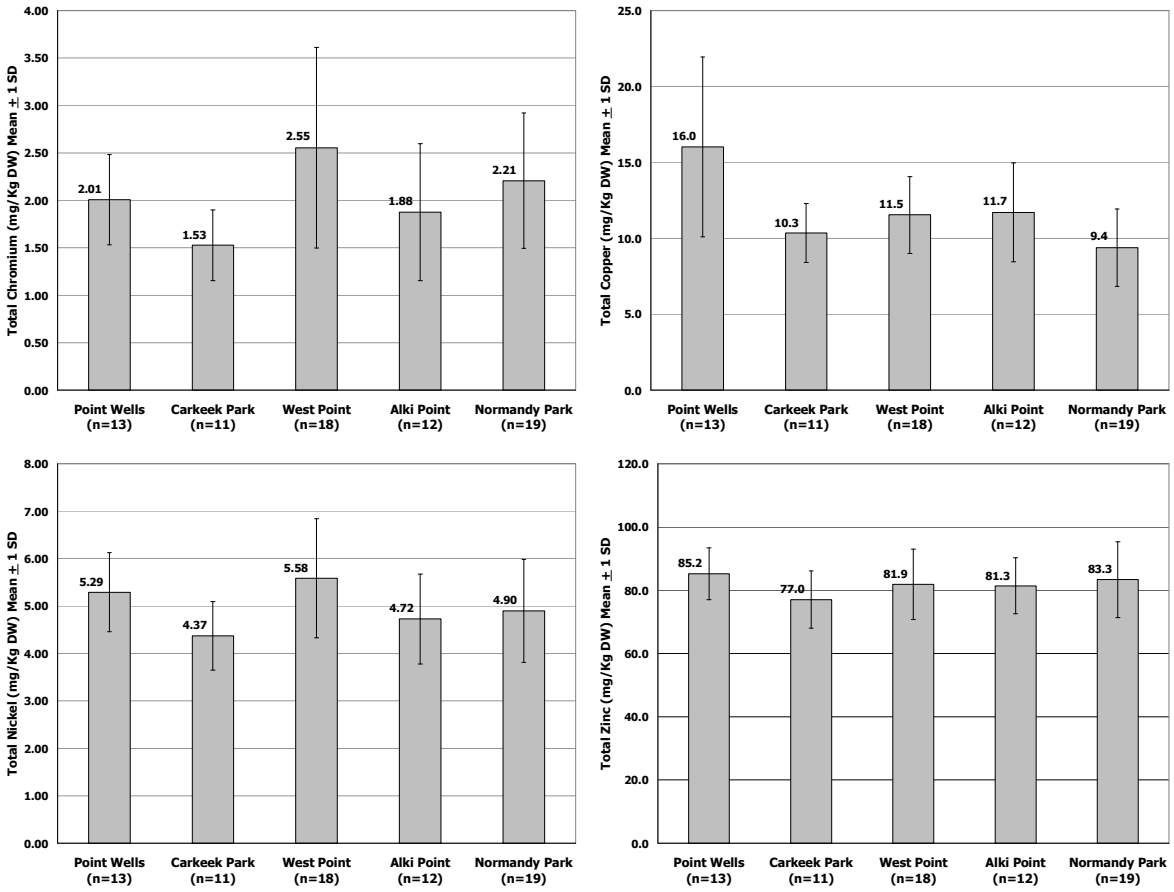

Figure 5-2. Spatial Comparison of Shellfish Tissue Metal Concentrations – 1998 to 2007

5.1.3 Organics

Seven shellfish tissue samples were analyzed in 2005 for 97 trace organic chemicals, including 70 semivolatile organic compounds, 20 chlorinated pesticides, and seven PCB Aroclors®. Of these 97 trace organic chemicals, only five were detected in one or more samples – benzoic acid, benzyl alcohol, beta-BHC (ß-benzene hexachloride), bis(2-ethylhexyl) phthalate, and PCBs.

Benzoic acid was detected in all seven samples at concentrations ranging from 2,690 to 6,390 µg/Kg on a wet-weight basis. Although benzoic acid is produced industrially and can be found in food preservatives and anti-fungal agents, among other uses, it is also a naturally-occurring degradation product produced by metabolic processes in shellfish. Benzoic acid is always detected in shellfish samples.

Benzyl alcohol was detected in four of seven samples, at concentrations ranging from 36 to 93 µg/Kg on a wet-weight basis. This compound was detected in samples from one outfall station, KSHZ03 (52 µg/Kg), and in samples from all three ambient stations; JSVW04 (93 µg/Kg), KSLU03 (91 µg/Kg), and MTLD03 (36 µg/Kg). Benzyl alcohol is a commonly-used chemical

found in a diverse array of products such as perfumes, soaps, solvents, pharmaceuticals, and bacteriostats. There are no regulatory criteria or guidance levels for benzyl alcohol in shellfish.

Beta-BHC was detected in four of seven samples, at concentrations ranging from 0.58 to 1.65 µg/Kg on a wet-weight basis. This chlorinated pesticide was detected at two ambient stations; JSVW04 (1.65 µg/Kg) and MTLD03 (0.58 µg/Kg), and two outfall stations; KSHZ03 (1.04 µg/Kg) and LSKS01 (0.99 µg/Kg). Beta-BHC has been detected previously in butter clam samples at similar concentrations and was widely detected in geoduck tissue samples during another King County study (King County, 2002). Beta-BHC is one isomer of the benzenehexachlorides pesticide mixture, the others being alpha, delta, and gamma. This mixture was widely used as a crop pesticide although its use has now been banned in the United States. Beta-BHC is the most fat-soluble of the four isomers as well as the most persistent in the environment. Gamma-BHC, also known as Lindane, is the one isomer still in use, as a prescription treatment for head lice and as a veterinary insecticide. Beta-BHC is one of the breakdown products of Lindane. There are no regulatory criteria or guidance levels for beta-BHC in shellfish.

Bis(2-ethylhexyl) phthalate was detected in all seven samples, at concentrations ranging from 180 to 235 µg/Kg on a wet-weight basis. Bis(2-ethylhexyl) phthalate is a common plasticizer and ubiquitous in the environment. Given the similarity of the concentrations detected in all seven samples, however, it is most likely that these detected values are artifacts of the sampling process, imparted to the tissue samples through handling with plastic-gloved hands or being stored in plastic bags during the sampling process.

Aroclor® 1254, one of the formerly commercially-produced PCB mixtures, was detected in one shellfish tissue sample, collected from Station KSSN05, at a concentration of 3.9 µg/Kg on a wet-weight basis. PCBs were widely used as insulating material until their production was banned in 1977. They are, however, present in old electrical transformers and capacitors still in use and resist degradation, once in the environment, due to their chemical structure. PCBs have not been detected previously in any shellfish tissue sample collected by King County, nor have PCBs ever been detected at Station KSSN05 in water, sediment, or algae samples. A potential legacy source for this PCB detection in shellfish tissue is unknown at this location. The detected value of 3.9 µg/Kg is extremely low – less than 0.2% of the FDA tolerance level of 2.0 ppm (parts per million) in shellfish (FDA, 2005).

Because so few organic analytes have ever been detected in butter clams, the analysis of trace organic compounds for the shellfish program was discontinued after the August 2005 sampling event.

5.2 Macroalgae

Macroalgae samples, consisting entirely of *Ulva spp.* (sea lettuce), were collected from seven beach stations in August 2005 and analyzed for 14 metals. Outfall beach stations sampled included Carkeek (KSHZ03), West Point (KSSN05), Alki (LSKS01), and Vashon Island (MSJL01). Ambient beach stations sampled included Point Wells (JSVW04), Golden Gardens

(KSLU03), and Normandy Park (MTLD03). Macroalgae metal results are summarized in Appendix D (Table D-1).

Beryllium, selenium, and silver were not detected in any of the macroalgae samples, which is consistent with previous years' results. Mercury was detected in all three ambient samples but not in any of the outfall samples. Macroalgae mercury concentrations in the three ambient samples ranged from 0.00394 to 0.00503 mg/Kg DW.

The trace metals arsenic, cadmium, chromium, copper, lead, nickel, and zinc were detected in all seven macroalgae samples. Table 5-3 shows the concentration ranges for these seven trace metals.

Table 5-3. Macroalgae Trace Metal Concentrations – 2005

Metal	Minimum	Maximum
Arsenic	4.28	9.93
Cadmium	0.53	2.15
Chromium	0.47	6.64
Copper	3.03	7.09
Lead	0.30	1.53
Nickel	1.79	7.41
Zinc	7.60	19.2

All values in mg/Kg DW.

Sampling and analytical inconsistencies in the macroalgae monitoring program have precluded the opportunity to perform spatial or temporal analysis of the data collected over the past several years. Macroalgae data are, therefore, presented only to provide the reader with the range of metals' concentrations detected in samples collected from seven representative King County beaches. The macroalgae monitoring program was discontinued in 2006.